

A Collaboration Network for Unmanned Aerial Vehicle Operation, Research and Education

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INTRODUCTION

The type and number of Unmanned Aerial Vehicles (UAVs) is increasing rapidly. However, operational UAVs are a high-demand, low-density asset and access is extremely limited due to higher priority taskings of these systems. Researchers and developers of UAV related systems, operations, and training rarely have access to an operational quality UAV and must resort to building their own systems. The effort required in developing a fully functional UAV system coupled with the logistics of airspace, operator training, and other flight related activities is a major undertaking.

The objective of a UAV Collaboration Network (UCN) is to extend the USAFA UAV flight and simulator capability using common Internet Information Technologies to local and remote users to reduce the barriers of engaging in UAV related education, research, and operations.

Typical scenarios for use of the UCN include classroom observation and control of both actual and simulated UAVs. Other uses include enabling other researchers or system developers to observe a UAV flight test of their designs from a remote location. Emergency first responders may also be able to log on to a UAV that is being operated on their behalf and observe the video and telemetry being provided. Users of UAV data such as GIS applications can develop their applications by easily accessing actual real-time UAV data being distributed over the UCN.

In short, the purpose of the UCN is to increase the accessibility to UAVs to accelerate the development of educational, operational, and training research activity in the UAV systems domain.

Research Objectives

Geo Registration

The term “Geo Registration” is used to indicate the task of determining a position coordinate for any feature on Earth and entering that information in a database. Most ground control stations record the telemetry and video on different systems. It often takes expensive and proprietary equipment to decode the data. A further challenge is synchronizing the data to the geographic position of the UAV video. This video geo registration is often a function provided within the GCS during live UAV operations but is seldom available via archived data or when retransmitting the video. The UCN will provide a method for distributing video along with the data needed to geo locate items of interest within the video.

Video and Telemetry Synchronization and Archival

The key challenge in extending “stove piped” UAV systems is in retransmitting the telemetry and video in a synchronized fashion both to enable geo registration and to increase the value of the video in providing situational awareness to the viewer. Items such as UAV airspeed, altitude, angle of bank and other parameters are extremely useful to many viewers while watching a live or archived video. However, this data must be synchronized to the associated video. The challenge for the UCN is to provide both the video and the telemetry using Internet streaming technologies while keeping the data keyed to each other such that any data set can be correctly correlated to a video frame to enable geo location. One goal of this research was to identify the most appropriate file format that would support all the information for both live and archived missions.

Full Mission Life Cycle Collaboration

Most UAV systems that provide remote video monitoring are non-interactive in nature. Video is transmitted to a remote location and typically displayed during the enroute portion of the mission. The UAV Operator's voice is often provided along with the video. The only interaction a viewer can have with the operator is through command and control communications channels outside the UAV monitoring system. The UCN provides an integrated interface to allow remote viewers to completely interact with all phases of a flight to include launch and recovery. By using Internet Voice over IP (VoIP) technologies, remote viewers can participate in the preparation, launch, operation, and recovery of a UAV mission through a single web-based interface.

Typical UAV System Architecture

The typical UAV system consists of the Air Vehicle itself controlled by a ground control station (GCS) comprising of one or more computers with which the operator interacts. These operator interface (OI) computers send commands and receive video and telemetry via the ground data transceiver (GDT). The size and complexity of the GCS varies greatly between UAV systems but the primary components remain the same.

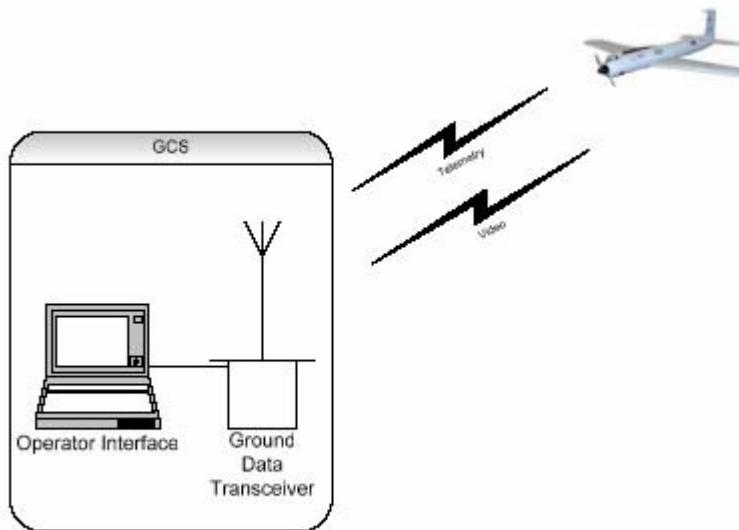


Figure 1: Typical UAV System Architecture

UAV Collaboration Network System Architecture

The UCN extends the basic UAV system by leveraging Internet Technologies to enable remote access to voice, data, and video systems of the existing UAV system. Figure 2 shows the proposed UCN architecture.

The UCN extends an existing GCS by adding a few software components to support the Internet Technologies needed to enable remote GCS stations to interact with the UAV system and support personnel.

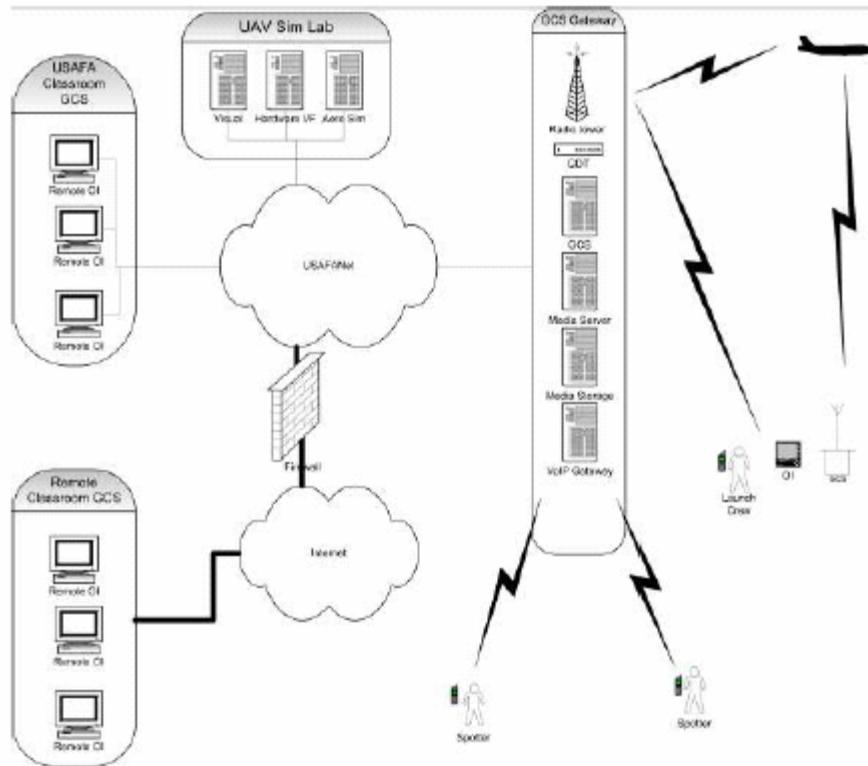


Figure 2: UAV Collaboration Network

A Voice Coordination Network utilizing a VoIP to radio Gateway enables remote GCS operators to communicate to launch personnel and spotters that are in the field via land mobile hand held radios.

A UAV Media Server is responsible for integrating telemetry and video from the existing GCS and delivering it via a streaming technology. The media server also handles commands and requests sent to the GCS via remote GCS OI stations.

The UAV Media Storage Server stores recorded versions of all transactions during a mission for playback within the system. This server also maintains a database of expanded data that will not fit within the single file format for UAV media. The next section provides a more detailed description of each of these components.

THE UAV COLLABORATION NETWORK (UCN)

Voice Coordination Network

In preparing for UAV operations that would involve remote operators, it became clear that a method was needed to enable communications between the remote computer users and field personnel that were launching and operating the vehicle.

Several technologies were considered including cell phone and repeater based hand held radios. Cell phones were eliminated due to the cost involved and with concerns over coverage. Repeater based radios by themselves were eliminated due to range limitations and not being scalable to large numbers of users.

The solution was a voice coordination network (VCN) that is a VoIP solution enabling multiple clients to coordinate on a virtual channel. This also enabled a security measure to be implemented that allows some users to listen only and others to transmit.

The VCN client software also needed to interface with handheld radios so that PC-based clients could talk directly to wireless radio users and visa versa. Figure 3 shows how the VCN design will enable handheld radio users to communicate with PC-based users. The key components being the VoIP software and the interface between the VoIP and the radio base stations represented by the towers in the figure. The two key components of the VCN include the VoIP software and the computer to radio interface.

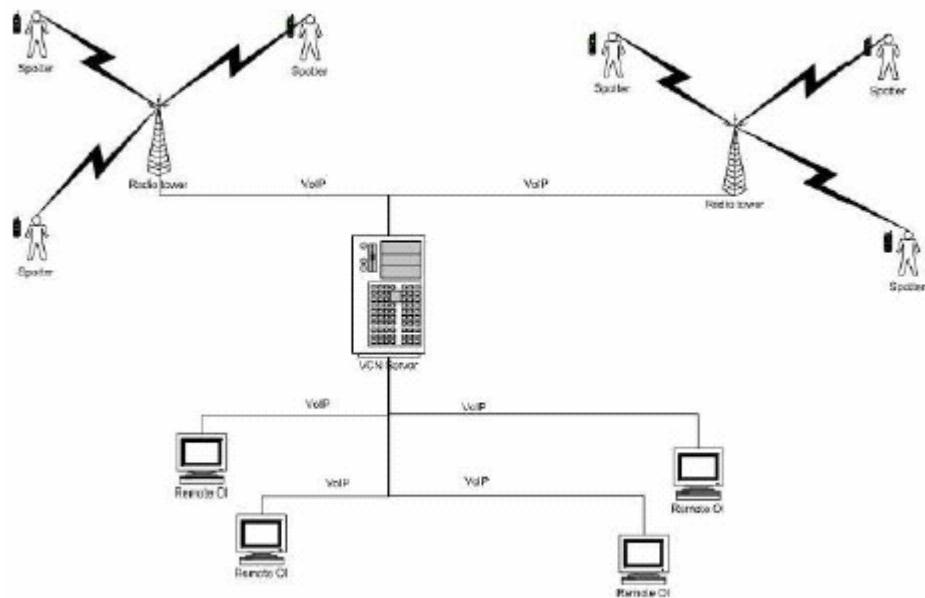


Figure 3: Voice Coordination Network

VoIP Software

In early 2002, several solutions for the VCN were researched. Several VoIP to Radio gateway designs began emerging in the Amateur radio community. The following were researched as possible enabling technologies for the VCN.

EchoLink www.echolink.org

Designed specifically for Amateur radio and requires users to authenticate against an FCC database to prove they are licensed to interface with the radios connected to the network. Rejected due being a “closed” system for use by persons not licensed by the FCC.

eQSO www.eqso.net

Does not require any special hardware. Server administrator can manage privileges of various users. This is the software selected for use as it was customizable and not restricted to amateur radio use.

iLink www.aacnet.net/radio.html

Requires a specialized hardware radio interface. Rejected due to the need for dedicated matching hardware.

IRLP www.irlp.net

Only creates a virtual repeater channel that can ONLY be accessed via a radio. Rejected due to this limitation.

WIRES-II www.yaesu.com

A commercial VoIP solution with matching dedicated radio interface hardware. Rejected due to cost and proprietary formats.

eQSO was selected because it provided the ability to have both private and public servers. The server software was also available under a free license for both amateur and non amateur use. Additionally the software provided basic security measures to control which clients were able to participate on a virtual frequency room (akin to an Internet chat room). Members joining the room could be assigned receive only or both transmit and receive privileges,



Figure 4: eQSO Server

Figure 4 above shows a screen shot of the eQSO server software running on a Windows 2000 server. The software allows the administrator to control how many rooms are available

and how many clients can connect. In the example above the server has logged two clients chatting in the "UAV 2" room along with some of their statistics.

Figure 5 below shows an example of the VCN client software that allows a user to connect to the room. The users see all of the other stations in the room and all transmissions are heard by all stations. In the example shown Station 1 is a remote operator at a computer in the classroom and Station 2 is a person at the USAFA soccer field using a handheld radio. The hand held radio transmits to another radio connected to a PC using the radio interface described in the next section. The computer that interfaces to this base radio is also running a client eQSO which provides radio control features via a serial interface to the radio interface module.

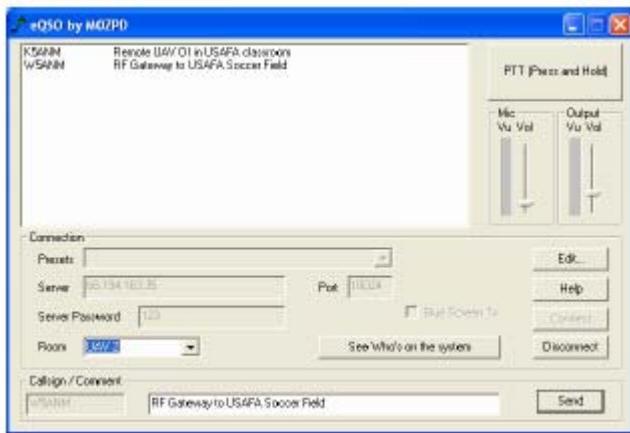


Figure 5: VCN Client Software

Figure 6 below shows a value added feature of the eQSO system called the system monitor. The system monitor acts a directory to allow users to find various radio related rooms and then to connect into a specific room. This is accomplished by having each server publish its information to a central directory server. The possibility of running a private directory server makes the eQSO software a viable option as the underlying software for the VCN.

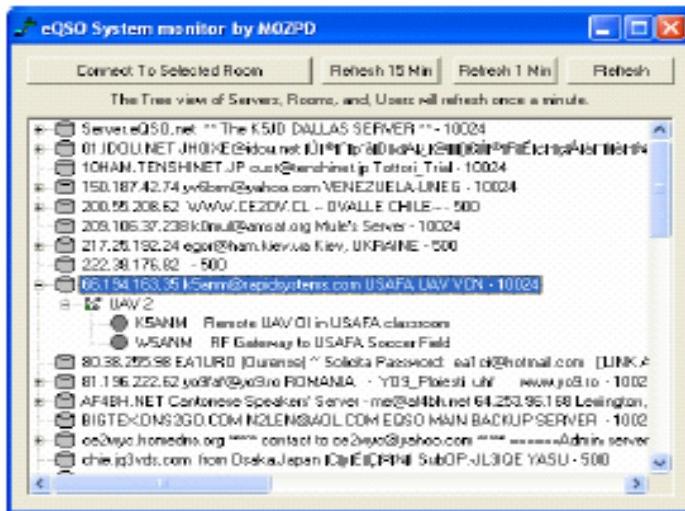


Figure 6: VCN Directory

VoIP to Radio Interface

eQSO provides the session management as well as the voice transport to enable VoIP communications. However, to extend the network based communications to analog mobile radios it is necessary to have a PC running the eQSO software and connected to a 2-way radio via a computer to radio interface. Several interface hardware solutions were explored but the preferred solution is a low cost commercial product designed by West Mountain Radio Inc. The interface is called a "rig blaster" and provides the audio path and transmit control between the computer and the radio.



Figure 7: "Rigblaster" computer to radio interface
with permission from West Mountain Radio, Inc.

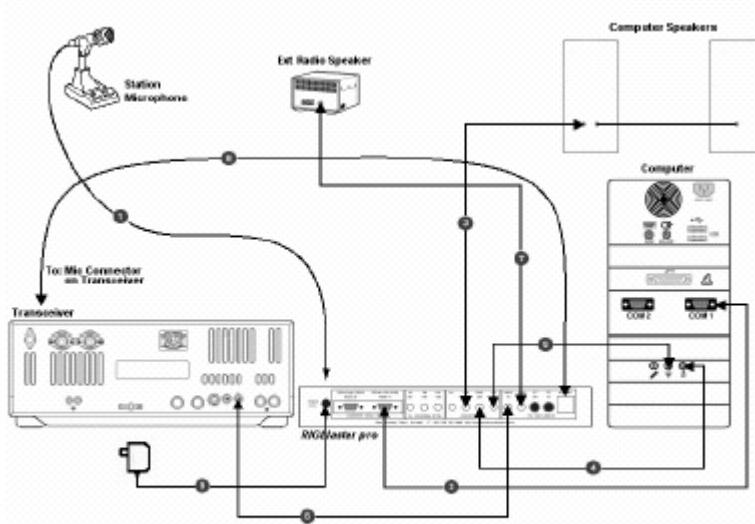


Figure 8: Radio to computer interface
with permission from West Mountain Radio, Inc.

UAV Media Server

The UAV Media server in figure 9 is the main component of the UCN that enables many of the objectives of this research. The UAV Media server captures audio from the VCN and also interfaces with the video and telemetry from the UAV GCS and combines all of the information into a single file format suitable for streaming via the Internet.

Several techniques for merging the video, audio and telemetry were explored to include encoding the telemetry as sub-audible data within the audio channel but the final solution leveraged an existing Internet Streaming media with almost ubiquitous use in Internet media today: Real Video.

The Real Video format was selected due to the availability of a Software Development Kit (SDK) that allows customized applications with the underlying codec. This codec was modified into a custom application used for encoding UAV video with UAV telemetry. This is the key enabling technology for implementing geo-registration of the video. Real video was also chosen because it allows a method for viewing and controlling the UAV video via a standard web browser. The web browser can embed the video display controller and JavaScript routines in the web page and can extract the meta data for each video frame.

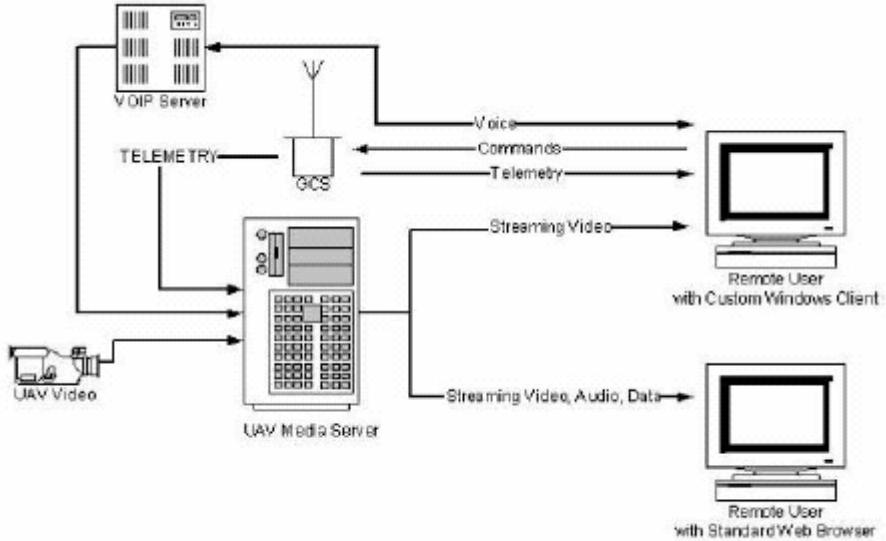


Figure 9: Media Management System

The software components for the UAV Media Server are shown in Figure 10. The shaded items are components that have been built, acquired, or are otherwise in place to complete a production UCN.

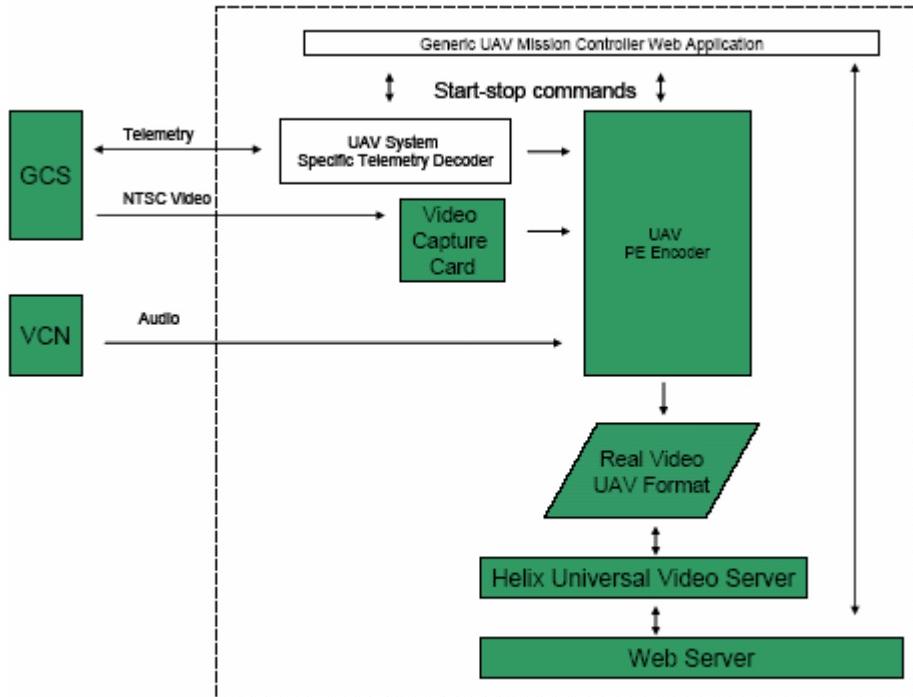


Figure 10: UAV Media Server Components

Generic Web Based Encoder Controller

The purpose of this application is to provide a means for clients accessing the UCN via a web page to start and stop a UAV session of either an archived or live UAV mission. This application has not been developed at this time but can be implemented using any web based server side scripting method supported by the selected web server such as ColdFusion, Asp, asp.net, php and others.

Telemetry Decoder

This component of the system is specific to the UAV system that is being accessed. Prototype versions of this component have been developed for the Desert Hawk and Silver Fox UAV Systems.

Video Capture Card

Any quality capture card that accepts NTSC video can be used. The prototype media server utilized an Osprey 100 Pro video capture card.

UAV Media Encoder

The UAV media encoder is a custom application based on Real Video 8.0 codec within an application that provides a method for adding telemetry information from the UAV to each frame of the video as it is encoded into the Real Video format. The following is an extract from the controller documentation created by Accordent Technologies specifically for this research:

The Encoder Controller (“PE-Controller”) is used to launch and control one or more encoders (Windows Media Encoder or Real Encoder) and is necessary for synchronizing non streaming content with a live video stream and for creating a synchronized archived file. Once loaded, the PE-Controller listens on a predefined port for incoming HTTP GET and POST commands (like a small HTTP web-server). Once a command is received, it returns a status about the command progress in raw text. Some of the command returns are in XML mode get, device, and so on. For a full list of commands, see the reference section about HTTP Calls.

The application can also run as a normal windows application (application mode) or as a background system service (service mode). Both modes share the same command configuration set.

In Application Mode, the user (person who is interacting with the encoder controller) can *directly* interact with the encoder just as he or she would with any other windows application. Video streams and settings can be directly configured and controlled. If an error occurs, the user will see a pop-up message stating the error.

In Service Mode, the user cannot directly interact with the Encoder Controller because it is running in the background as an NT service; the application should show up on the Administrative Tool’s Service Panel as “PresenterPRO Encoder Controller” service. Its actual “service” name is **pe_controller**. Auto-start is set to manual by default. Before starting the service, ensure there is not another instance of the encoder controller in running application mode. In addition to the Service Panel, the DOS command window also can be used to start or stop the encoder controller service by running the following commands, respectively:

Net start pe controller

or

Net stop pe controller

Error logs are stored in the same location as the encoder controller program itself (**pecontroller.exe**) with the following format **<date>_log.txt** and can easily be accessed via the “Logs” button on the “Main” tab of the Encoder Controller when in Application Mode.



Figure 11: UAV PE Controller in Application Mode



Figure 12: Playback of UAV Encoded Video with Data Extraction

The encoder controller created by Accordent provides a software development kit (SDK) for creating UAV video/data integration systems. The application programming interface (API) specified by the researcher and created by Accordent provides an extreme amount of flexibility for continuing integrating the UCN with multiple UAV systems.

Helix Universal Server

The Helix Universal Server is a free video streaming server that manages the streaming of video requests by web clients. The Helix server is responsible for buffering and maintaining a quality of service based on the clients selected bandwidth, www.real.com.

Web Server

There is no restriction to the web server used for the UCN. The prototype was implemented on a Windows 2000 server since the remaining software was based on windows components. The only requirement for the web server is that it support server side scripting engines and provide mime-type support for the real media content being supplied by the Helix Universal Server.

Media Storage Server

The concept for a Media Storage Server is based on a need to manage large file sizes of UAV missions. Since the metadata space of each frame in the video is extremely limited it may be desirable to implement a database with an expanded set of telemetry. A pointer to this expanded set will then be stored in the metadata with each frame of video so that it can be referenced at a later date. No further work on the storage server has been completed.

UAV Simulator Interface

A hardware in the loop simulator is a critical component for training and testing before actual UAV flight operations take place. The simulator uses actual UAV hardware and software components to increase the fidelity and concurrency between the simulation and reality. Access to this simulation environment is provided via the UCN. The Silver Fox simulator was used to test the various components of the UCN.

The primary components of the simulator include the following:

1. UAV avionics hardware and software
2. UAV flight simulation system
3. UAV visualization system
4. Instructor Operator Console
5. Student Operator Console

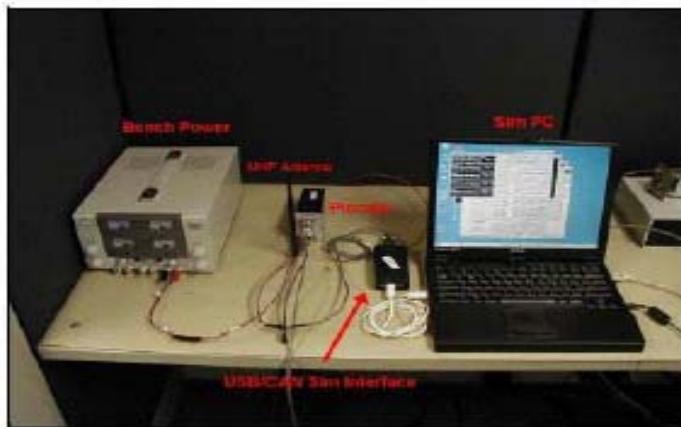


Figure 13: Silver Fox UAV Simulator

The simulator environment can be operated in a stand-alone mode or can be accessed remotely via the UCN by a network connection on the UAV flight simulation system.

Functional Tests of the UCN

Functional tests of the UCN components have shown that the video synchronization and delivery scheme is viable. The task of integrating the components of the described components remains. It is desired that USAFA cadets complete this integration in senior design courses and fully implement the UAV Collaboration Network with operational UAVs.

UAV Systems used for UCN Functional Testing

Two operational UAV systems were used for functional testing of the UCN concept and various components. The Silver Fox by Advanced Ceramic Research is a Navy UAV used by special forces. The Desert Hawk UAV system is operated by USAF security forces for force

protection missions. Both of these systems were selected for their size and cost and were good fits for integration tests with the UCN. Each system is described in more detail in the following sections.

Silver Fox UAV System

The Silver Fox is a glow-fuel engine driven aircraft with fully autonomous autopilot. The aircraft can also be flown and landed manually. The avionics package is called the piccolo made by Cloud Cap Technologies. The system is hand or catapult launched and can fly upwards to 65 mph.

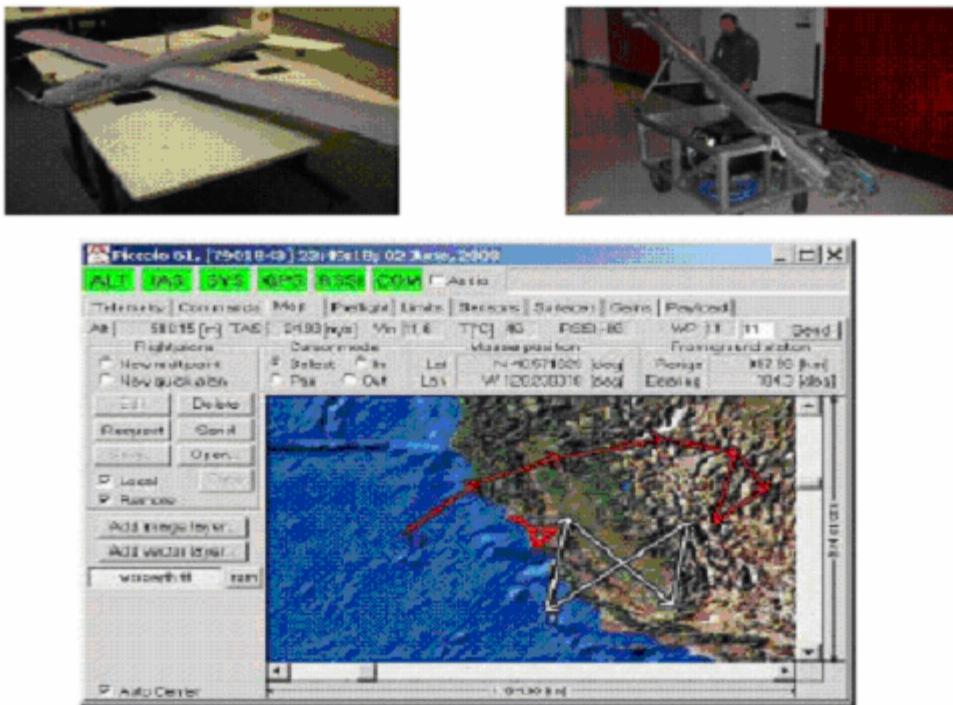


Figure 14: Silver Fox UAV System

Desert Hawk UAV System

The Desert Hawk System is an electric powered UAV that is fully autonomous after being launched with a bungee system. The aircraft can be commanded in semi-autonomous mode known as "u-drive" and is landed under computer control as programmed by the operator.

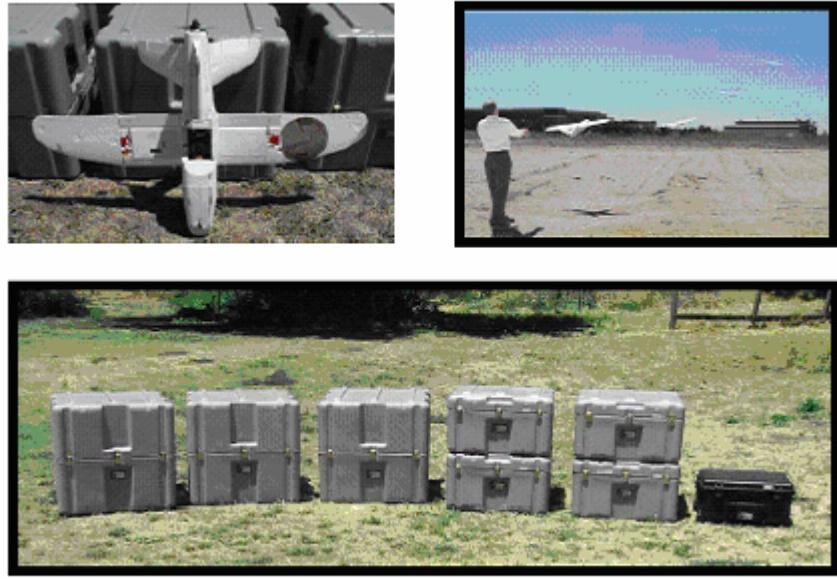


Figure 15: Desert Hawk UAV System

Test 1: Remote access of UAV Video and Data via Web Interface

The first functional test of the UCN was to ensure the heart of the system – the PE UAV Encoder would properly encode telemetry and video together and provide a means for play back. The first step in testing this functionality involved using the PE Controller to manually record archived video along with archived telemetry from files. The next step involved connecting the Silver Fox UAV Simulator to the UCN and recording a simulated flight in real time.

The results of this test showed that the system was functional. A recorded video file with embedded telemetry was created and played back using a web browser. It provided a proof of concept using recorded data that live data could also be recorded in this fashion.

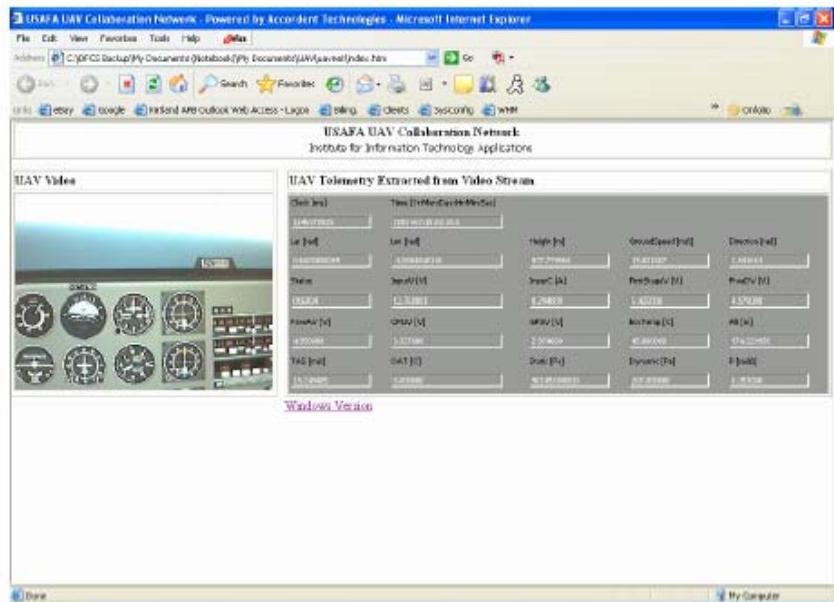


Figure 16: Web based extraction of telemetry from UAV Video Format

Test 2: Remote command and control of GCS

The desired end-state for the UCN is a web based interface that starts, stops, and controls the display of UAV mission video and data. To enable the operation, a helper application must be developed that can start and stop both the PE Encoder and the target GCS telemetry stream. A simple proof of concept windows application was developed for testing this integration and is shown in Figure 17. A more robust web based application remains for future research and development.

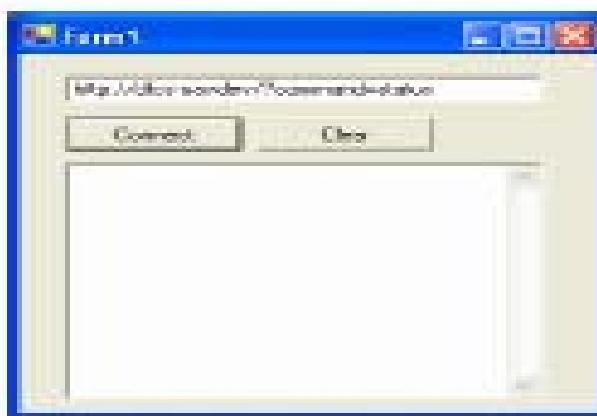


Figure 17: Command And Control Application

Test 3: Geo Registration

A key benefit of the UCN is that it provides a UAV application development framework with endless possibilities for extending the UAV information. A key objective of the research was to take UAV video and telemetry and integrate it into the GeoBase system for use by

command and control elements. The first step of this integration was taken when a single file format of UAV Video was streamed to a GeoBase application and displayed the movement of the UAV on a map as well as the video from the UAV. Much more integration is required to enable live streaming of video and telemetry but the functional test showed that the mix of technologies was feasible and effective. The UCN was shown to be a very flexible architecture.

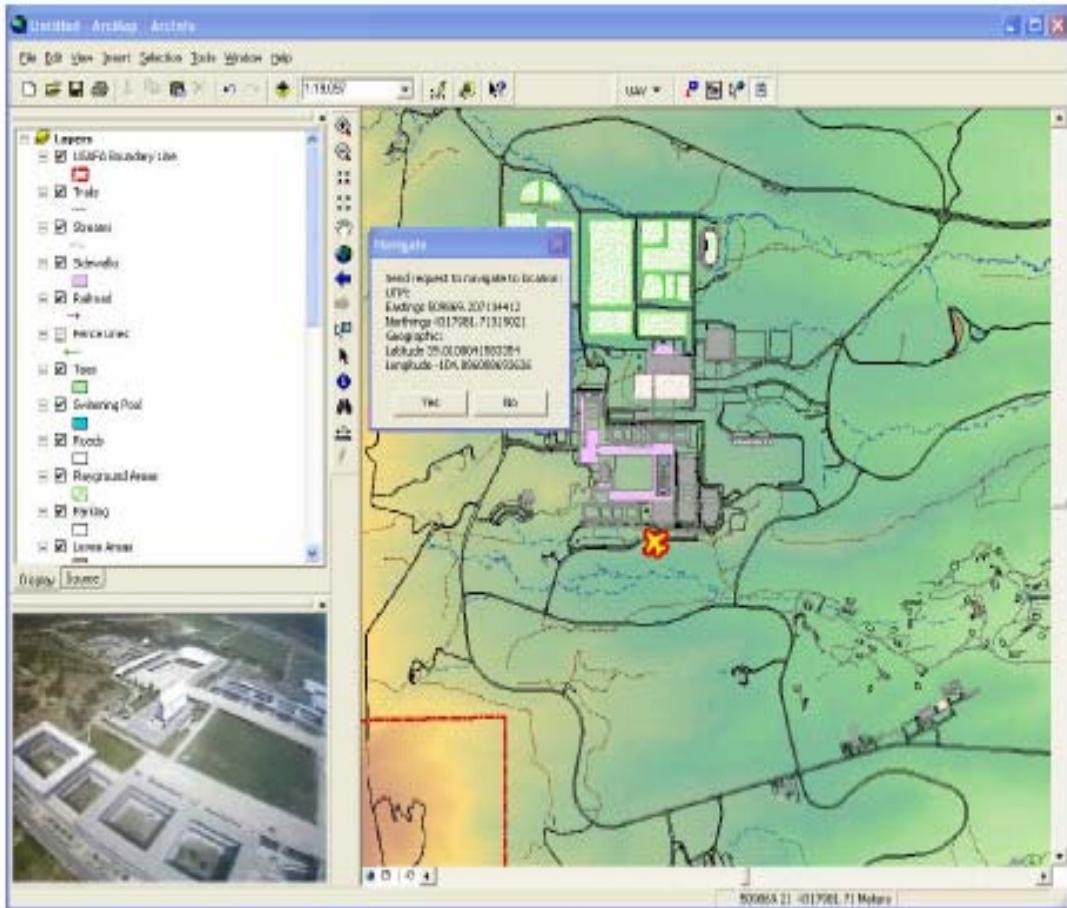


Figure 18: UCN Integration with GeoBase Application

Test 4: VoIP to Radio Test

The eQSO VoIP radio Interface was installed on an Amateur Radio VHF station in Colorado along with both VHF and UHF radio transceivers in California and Texas. The amateur radio operators participating in the test enjoyed 100% uptime in communications and logged contacts with over 1500 stations in 25 countries over a period of 6 months. The eQSO is a stable and viable solution for integrating VoIP and radio communications as a solution for the VCN.

Project Summary

The UCN represents a viable architecture for an enterprise class UAV collaboration system. The functional tests completed are the results of many hundreds of hours of work pulling together the various components and technologies. The result has been a positive indication that the technology will support a very low cost and effective method for remote users to access and control UAV sensors. A significant amount of work remains to integrate the various components into a production system that can be used with multiple UAV systems.

UCN Status and Work Remaining

The pivotal component of the UCN is the UAV Media Server and central component of the media server is the PE controller. With the UAV PE controller completed the remaining components can be integrated into a complete solution. The servers, GCS components, and VoIP to Radio gateway equipment to implement the media server have been installed in the USAFA UAV Lab. What remains is an integration effort to set up a web server and associated web applications to interact with the underlying components.

The underlying software components used during functional testing may need modification or may need to be recreated from scratch all-together based on further use and discovery of any limitations. However the foundation for each component has been established and proven through the functional testing.

A one or two semester cadet systems engineering effort may be an appropriate avenue for completing the integration of the UCN.

Glossary

API	Application Programming Interface
GCS	Ground Control Station
GDT	Ground Data Transceiver
GIS	Geo Information Systems
IP	Internet Protocol
NTSC	National Television System Committee (Standard for Video in the United States)
OI	Operator Interface
PE	PresenterPro Encoder (Developed by Accordent)
SDK	Software Development Kit
UAV	Unmanned Aerial Vehicle
UCN	UAV Collaboration Network
VoIP	Voice over IP
VCN	Voice Coordination Network

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Advanced Ceramic Research Inc for their assistance in training and operating the Silver Hawk UAV.

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ABOUT THE INSTITUTE

The Institute for Information Technology Applications (IITA) was formed in 1998 to provide a means to research and investigate new applications of information technology. The Institute encourages research in education and applications of the technology to Air Force problems that have a policy, management, or military importance. Research grants enhance professional development of researchers by providing opportunities to work on actual problems and to develop a professional network.

Sponsorship for the Institute is provided by the Assistant Secretary of the Air Force (Acquisition), the Air Force Office of Scientific Research, and the Dean of Faculty at the U.S. Air Force Academy. IITA coordinates a multidisciplinary approach to research that incorporates a wide variety of skills with cost-effective methods to achieve significant results. Proposals from the military and academic communities may be submitted at any time since awards are made on a rolling basis. Researchers have access to a highly flexible laboratory with broad bandwidth and diverse computing platforms.

To explore multifaceted topics, the Institute hosts single-theme conferences to encourage debate and discussion on issues facing the academic and military components of the nation. More narrowly focused workshops encourage policy discussion and potential solutions. IITA distributes conference proceedings and other publications nation-wide to those interested or affected by the subject matter.